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Measuring the sustainability impact of circular economy practices: comparing academia and practice

Aligning the methodological framework with a fuzzy concept

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Abstract

Circular economy (CE) has become a central concept for sustainable production and consumption since its introduction into the public eye. As part of the European research project CRESTING under the Horizon2020 programme, one of the working packages aims to evaluate whether CE actors and networks actually perform according to their sustainable image. Indeed, to ensure CE does not only increase the economic performance of companies, but also delivers on its promises regarding the social and environmental dimensions of sustainability, it is vital to measure the impact of CE practices in an integrated way. In the absence of integrated measurement, CE would risk becoming a purely profit-driven endeavour, potentially having adverse effects on other sustainability aspects. Especially sustainability measurement approaches, but also approaches to measure circularity take a multitude of forms. Therefore, this contribution aims to set a foundation to assess suitable approaches for measuring the sustainability performance of CE practices in the private sector. Two methods are applied. The first is a systematic literature review to analyse frameworks, methodologies, methods, indicators and tools which measure the sustainability impact of CE practices. In a second step, literature is compared with practical examples of sustainability measurement approaches from private actors in Italy and the Netherlands. The CE practices are to be identified through a questionnaire for companies with CE best practices. To pertinently apply these methods, the paper identifies and connects relevant CE concepts, which are Industrial Ecology (IE), one of the theoretical foundations of CE, for assessing geographically delimited areas and closed-loop supply chain management and reverse logistics (CLSCM/RL), a promising source of suitable measurement approaches for assessing the impact throughout a product's life cycle. Furthermore, the paper stresses the importance to include the social dimension in the assessment, as it is only marginally discussed in the concepts influencing CE. In contrast, the economic dimension plays a crucial role in the concept, though it is often referring to profit-related instead of prosperity-related variables. Based on these two clarifications, the article presents a literature review protocol as well as the outline of a questionnaire to capture the practitioner perspective which can then be juxtaposed to the findings in academic publications. Identified gaps and overlaps will provide input for improving existing measurement approaches from a pragmatic point of view.

Keywords: Circular economy, industrial ecology, closed-loop supply chains, sustainability assessment, measurement

1. Introduction

Circular economy (CE) has become a central concept of sustainable production and consumption since its recent introduction into the public eye (Ghisellini et al., 2016). However, the concept, put back on the landscape by the Ellen MacArthur Foundation (EMF), the Chinese and European policy makers (Geng et al., 2012; Jacobi et al., 2018; Su et al., 2013), is not as novel as it might seem (Reike et al., 2018). Several approaches to implement and assess CE practices, meaning circular business models, strategies and product solutions, have already been developed and practiced in the field of industrial ecology (IE), particularly industrial symbiosis (IS) (Bruel et al., 2019; Saavedra et al., 2018). Lazarevic and Valve (2017) state IE tradition has the largest practical influence on developing CE practices and thus can play a vital part in establishing viable measurement approaches. A second vital strand of research is supply chain management and closed loop supply chain management and reverse logistics (CLSCM/RL) in particular, which has dealt with similar issues as CE (Homrich et al., 2018; Stindt, 2017). While several scholars have reviewed CE measurement approaches which evaluate the circularity of products or the progress towards circular economy (Elia et al., 2017; Moraga et al., 2019; Saidani et al., 2019), there are limited contributions which evaluate whether CE actors and networks actually perform according to their sustainable image. This paper presents a conceptual framework for developing sound performance measurement methodologies, methods, indicators and tools to measure the sustainability impact of CE practices.

For this endeavour it is first essential to define what is meant by the concept of CE as well as sustainability. While the CE concept is rather recent, still fuzzy and in large parts based on public and private practitioners (de Jesus and Mendonça, 2018; Geisendorf and Pietrulla, 2018; Kirchherr et al., 2017; Korhonen et al., 2018), the concept of sustainability is more mature and well documented in academia (Geissdoerfer et al., 2017). In the plethora of proposed CE definitions, making a correct choice is hardly possible. Therefore, the authors have opted for a definition made after considering numerous academic contributions. Kirchherr et al. (2017) have reviewed 114 CE definitions from scholars and subsequently contributed their own: *"A circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations" (p. 224).*

Taking this consensus-based definition as foundation of its analysis, the paper aims to identify whether the contemporary measurement practice corresponds to it. In its current form, the wording does seem to integrate the three main pillars of sustainability from a business perspective: the environment, the economy, and society (Elkington, 1998) and considers intergenerational fairness, officially anchored in the most renown sustainable development (SD) concept in the Brundtland convention (WCED, 1987). Remarkably, the CE definition also mentions economic prosperity instead of "economic growth" or "profit", directing towards an understanding of sustainability where economic prosperity is mainly at service of "integral ecological and social fairness" (Vermeulen, 2018). For this paper, the concept of sustainability views Elkington's (1998) Triple Bottom Line (TBL) as People, Planet and *Prosperity*, as opposed to the frequently used People, Planet and *Profit* trilogy in the private sector.

However, positive sustainability impacts of CE practices have rather been assumed than measured since there are potential trade-offs between circularity and sustainability (Ghisellini et al., 2016; Murray et al., 2017). Moreover, Geissdoerfer et al. (2017) state that the beneficiaries of CE are mostly private sector actors, while the whole society is meant to benefit from more SD. This results in a different prioritisation of the three sustainability dimensions for CE, which mainly aims for economic profitability through more efficient resource use and thus less environmental impacts (Garcés-Ayerbe et al., 2019). Meanwhile, social sustainability is merely indirectly linked to CE through e.g. job creation (Geissdoerfer et al. 2017). This compromised social dimension of CE has caused many scholars to reconsider the use of CE practices as a tool for SD (Ghisellini et al., 2016; Murray et al., 2017; Saavedra et al. 2018; Suárez-Eiroa et al., 2017). The unclear positioning of the social dimension in the CE concept has in turn affected the development of measurement approaches for social sustainability. Limited standardisation and the fuzzy conceptualisation of social metrics and evaluation methodologies further aggravates social impact measurement (Sousa-Zomer and Cauchick-Miguel, 2017).

Just as in the general sustainability assessment (SA), the SA related to CE faces the issue of integrating the three sustainability dimensions (Sala et al., 2013), even more so, as the social one is not properly defined. An SA is inherently complex and its results cannot often be reduced to a single sustainability value. Even within each of the three dimensions, Seager and Theis (2004) consider the synthetisation to one value to be an oversimplification, leading to a loss of information. However, given limited time an expertise, private and public actors usually prefer multifaceted information to be summarised into a single number to facilitate comparability (Barbiroli et al., 2006; Bocken et al., 2016).

To develop methodologically sound and applicable measurement approaches it is thus essential to meet academic claims to completeness with a suitable amount of pragmatic insights on the formers' practicability. To compare the academic and practitioner perspective, the first part of the conceptual framework is dedicated to the question on how to analyse the academic discourse on sustainability impact measurement of CE practices. This is to be answered by a literature review (Creswell and Creswell, 2018), of which the structure and conceptual considerations are presented in this paper. The second part outlines what characteristics an assessment of CE practices applied in the private sector should have. The outline of a qualitative survey

(Jansen, 2010) for companies considered as front-runners in implementing CE practices is used to establish best practices. This proposed mixed methods approach (Creswell and Creswell, 2018) aims to obtain a holistic picture of both academic and private perspectives on measuring the sustainability impact of CE practices. A comparison of the two fields should enable scholars to establish common ground as well as gaps between the academic and practical sphere.

The document is structured as follows. In part two the mixed methods approach, including a systematic literature review and a survey, is presented and justified. Part three lays out both conceptual and terminological considerations necessary when identifying suitable CE measurement approaches and how these considerations are included in the methods. A summary of the main findings and their influence on future research are presented in part four.

2. Methods

2.1 Systematic literature review

As a first step, the article aims to shed light on current practice of measuring the impact of CE practices on the sustainability dimension from an academic perspective. The goal is to provide an extensive overview of methodologies, methods, indicators and tools already applied for SA in CE or that are deemed suitable for application in CE. Then, the research should also address the different ways in which the measurement of circularity and sustainability are connected. For this purpose, the authors propose a systematic literature review. The review is to be structured according to Zumsteg et al. (2012), who developed a Standardized Technique for Assessing and Reporting Reviews of Life Cycle Assessment Data. This format is recommended since many of the main assessment methodologies in CE and IE rely on life cycle thinking (LCT) (Boons and Baas, 1997; Chertow, 2000). Accordingly, the literature review should be structured as follows: an introduction, a rationale for the review in section two, followed by a more detailed description of the review question and objectives in section three. In section four, the methodology is laid out in the review protocol. Thereafter, the fifth section should discuss the results of the review, concluding the paper with an outlook on future research.

As basis for discussion in part three of this article, the four parts of the review protocol are laid out here:

- Review question(s)
- Selection criteria specifying inclusion and exclusion criteria
- Literature search sources and search phrases
- Evaluation

The protocol is adapted from the review of Life Cycle Sustainability Assessments (LCSAs) by Tarne et al. (2017). This methodology is chosen since the LCSA is viewed by multiple scholars to be the most comprehensive and operable SA measurement framework, “best at preventing burden shifting between stakeholders in the value chain” (Niero and Hauschild, 2017, p. 1; Sala et al., 2013).

2.2 Qualitative Survey

In a second step, the outline of a survey is developed to capture the perspective of practitioners on measuring CE impacts on sustainability aspects. The survey can be labelled a qualitative survey (Jansen, 2010), because it does not aim to analyse the frequency of certain member characteristics in the sample, but rather the diversity of these characteristics. This means the study is less aimed at how many companies use a certain CE measurement approach (even though this statistical data will also be recorded), but more what kind of approaches are used by companies of different sizes, different sectors and in different geographical regions. The sampling procedure, i.e. the selection of respondents, follows a mix of purposive sampling as well as network sampling (Hibberts et al., 2012). As CE is a rather recent concept, the number of self-proclaimed circular companies is limited (Kalmykova et al., 2018). To identify companies with extensive CE practices, the authors looked at existing CE networks in Italy and the Netherlands, two front-running countries in this field. These networks were either set up by private companies, associations or through public-private partnership initiatives and explicitly include the advancement of CE or IS

in their mission. Hence the sample is composed of CE network members, as these companies are assumed to be front-runners in their field. After all, it is not the goal to describe the CE measurement ambitions of an average company, but to identify best practices.

The questionnaire is drafted according to the seven-step framework of Gideon (2012), focusing on surveys for social science. These are the following:

- *Step 1: Define conceptual and construct variables according to the research objectives*
- *Step 2: Formulate preliminary survey items according to the above constructs*
- *Step 3: Examine preliminary questionnaire items for the following:*
    - *3.1 Relevance to the main research topic*
    - *3.2 Relevance to other questionnaire items*
    - *3.3 Logical flow*
    - *3.4 Avoid double-barreled questions*
    - *3.5 Avoid double negative questions*
    - *3.6 Avoid unnecessary repetitiveness*
    - *3.7 Avoid "leading" or "loaded" questions*
    - *3.8 Avoid biased questions*
    - *3.9 Use simple and direct language*
    - *3.10 Items should be short, clear, and precise*
    - *3.11 Determine what type of item will best examine the concept (e.g., an open-ended,*
    - *close-ended/multiple-choice, or ranking question)*
    - *3.12 Make sure all possible responses are included*
    - *3.13 Use simple items to measure complex concepts*
    - *3.14 Triangulate items to introduce complex concepts and ensure reliability*
- *Step 4: Run an empirical examination in a small representative study (pilot study)*
- *Step 5: Correct and rephrase items according to findings from previous stage*
- *Step 6: Write an introduction and instructions*
- *Step 7: Make any final adjustments and modifications (p. 94).*

As these steps apply to paper-based, telephone, in-person as well as online questionnaires, special attention is attributed to the fact that the questionnaire is web-based and will be sent out by email (Lozar Manfreda and Vehovar, 2009).

3. Results and Discussion

The following section is structured into two parts. First, some conceptual clarifications are presented which are necessary to conduct a fruitful literature review and provide the basis for the survey questions. The findings from these sections are then included into the review protocol of the systematic literature review on the one side and in the structure and execution of the survey on the other.

3.1 Untangling conceptual overlaps

While setting the rationale for the literature review, it became clear that the connection of CE and IE, as well as the relation to CLSCM must be clarified. Homrich et al. (2018) find that two research clusters currently dominate in CE which are the IE cluster on the one hand and the supply chain-oriented cluster on the other. These two strands of research are not yet well connected (Homrich et al. 2018; Stindt, 2017) and thus a first attempt to do so is presented here. Given that CE is a recent concept and thus the measurement approaches for CE practices are limited, the CE definition is operationalised through well researched approaches such as IS, coming from an IE context (Saavedra et al. 2018). White (1994) defines IE as

"the field of the flows of materials and energy in industrial and consumer activities, of the effects of these flows on the environment, and of the influences of economic, political, regulatory and social factors on the flow, use and transformation of resources."

This definition shows high overlap with most of the CE characterisations and substantiates the conceptual proximity. Besides frequently being considered as central tool to achieve SD (Ehrenfeld, 2007; Gibbs, 2009), IE is structured into the same three levels as CE, though the meso level refers to the inter-firm level, instead of only eco-industrial parks (EIPs). EIPs are on the same system level as product-cycles, collectively making up the inter-firm (meso) level (Chertow, 2000). However, it is important to state the different perspectives and end-goals which IE and CE take. While IE aims to modify production-systems to imitate natural ecosystems (Frosch and Gallopoulos, 1989), the end-goal of the CE is a closed-loop economy with zero-waste, where products have a design to re-design (Murray et al., 2017). This is operationalised in two interrelated life cycles, first defined by Reike et al. (2018), namely the *Product Produce and Use* Life Cycle and the *Product Concept and Design* Life Cycle. Both life cycles accommodate several value retention options such as reuse, reduce, recycle and refurbish, to name a few. The relevant measurement approaches for the current research are expected to mainly address the sustainability impacts of the Product Produce and Use Life Cycle, as the impacts of the Product Concept and Design Life Cycle are indirect.

As a conceptual counterpart to those two life cycles, IE on a meso-level can take two forms. One is IS, which

"engages traditionally separate entities in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity" (Chertow, 2000, p. 314).

IS can thus roughly be categorised as IE operationalisation in the form of an EIPs in a geographically delimited area, while IE can also take the form of a product-cycle, considering the environmental and economic impacts of the whole life-cycle of a product (Boons and Baas, 1997). Therefore, measuring the sustainability impacts of IS is mostly limited to the impacts in a certain location, whereas the product-cycle perspective accounts for effects that might occur far away from the production site, during the use phase or disposal of a product (Korhonen, 2002). In this respect, Life Cycle Thinking (LCT) is the most frequently used measurement rationale (Boons and Howard-Grenville, 2009).

While IS methodologies are more suitable for monitoring organisational clusters in a locally delimited area, though the size of the area can vary considerably, companies applying CE practices often operate at several geographical locations. Besides the product cycle perspective of the IE, a field already addressing this problematic in further detail is closed-loop supply chain management and reverse logistics (CLSCM/RL). According to Guide and Wassenhove (2009), CLSCM *"is the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time"* while RL is the *"process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal"* (Rogers and Tibben-Lembke, 1998). From this definition no explicit social and environmental goals are apparent in CLSCM/RL. However, some argue CLSCs are sustainable per se (Quariguasi Frota Neto et al., 2010), though not including the social dimension. Therefore, the research gap between CLSCM/RL and sustainability has to be closed to obtain pertinent measurement approaches (Godvidan et al., 2015).

Stindt (2017) and Godvidan et al. (2015) underline the similarities and overlaps of IS and CLSCM/RL. They lay out well-established measurement methodologies mostly based on LCT, which are yet to be complemented by more CLSCM/RL-specific approaches such as presented by other scholars (Butzer et al., 2017; Genovese et al. 2017; Halog and Manik, 2011; Jain et al., 2018; Topi and Bilinska, 2017; Xu, 2009). According to Homrich et al. (2018), no publication has explicitly addressed CE, SD, IE and CLSCM/RL together. Figure 1 aims to provide an overview of the relation of these concepts and serves as foundation for the literature review.

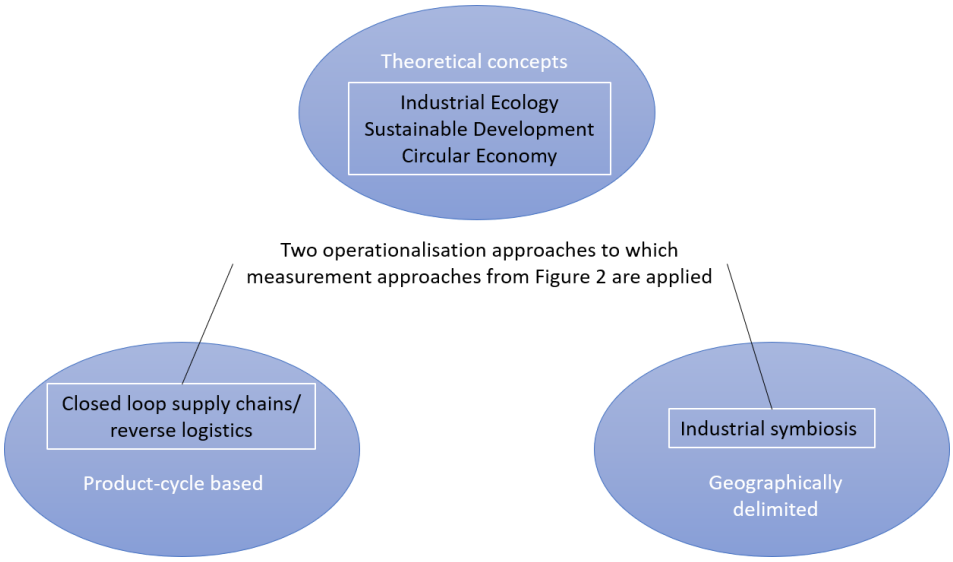

Figure 1. *Conceptual foundation of CE measurement (by authors).*

3.2 The missing social dimension and the misunderstood economic dimension

After clarifying the interconnections between the different concepts, assigning them to the respective operationalisation levels, another main problematic needs to be addressed. The sustainability dimensions implicitly included in CE are environmental and economic (Ghisellini et al., 2016), while the assessment of the social dimension often falls short (Homrich et al., 2018). Given that the authors rely on the theoretical background of IE, the position of the social dimension in IE needs to be better understood first. Sahakian (2016) argues the apolitical stance of IE does not consider social power relations and thus inhibits the practicality of the concept. It is thus crucial to ensure CE does not follow suit. The impact of CE practices on the social dimension ought to be assessed to prevent the depolitisation and decontextualization of the concept, as has happened to IE (Gibbs, 2009; Moreau et al., 2017). Besides the sparse social impact assessment, Vermeulen (2006) points out the limited integration of social theory into IE, merely applied when it comes to the application of IE practices. He also claims that the sluggish mainstreaming of IE is in part due to the limited analysis of the social context where IE practices were meant to be embedded in. Various scholars (Boon and Baas, 1997; Chertow, 2007; Gibbs, 2009; Surana et al., 2005) established cooperation and trust of product related or geographically delimited networks cannot be forced or extensively planned. To incentivise coordination instead of competition, economic incentives are not enough for actors to take up IE practices (Boons and Howard-Grenville, 2009). Therefore, scholars propose to support private actors with analytical and planning management tools to better assess social impact as well as further cooperation (Moreau et al., 2017; Vermeulen, 2006). This research will focus only on analytical management tools providing information on the sustainability impact of CE practices. Besides the vague conceptual integration of the social dimension, its diverse measurement strategies bear extra challenges when aggregating and weighting results within as well as among the different sustainability dimensions (Iacovidou et al., 2017).

While the social dimension is often assessed superficially, the economic dimension is mostly approached from a business perspective. Therefore, the operationalisation of this dimension frequently results in establishing indicators accounting for the profitability of a company or business practice (Vermeulen, 2018). This does not correspond to the prosperity described in the introduction, which refers to a macro-outcome and not merely a means, such as economic growth. The latter can go hand in hand with social and environmental fairness but is no precondition for it. It follows that one of the most prominent methodologies to assess the economic dimension from an LCT perspective, the Life Cycle Costing (LCC), does not represent the economic dimension in terms of societal prosperity. Therefore, an LCSA, including the Life Cycle Assessment (LCA), LCC and the social LCA (S-LCA), lauded as one of the best ways to assess sustainability (Sala et al., 2013) does only assess sustainability to a limited degree (Vermeulen, 2018). It needs to be stressed however, that profitability is still a vital metric on a company level to determine the feasibility of sustainable business solutions. Yet profit should only be a means to achieve

societal and environmental fairness and not an end in itself (Vermeulen, 2018). Therefore, the LCSA needs to be complemented to embody prosperity, which will require different indicators depending on the system level analysed. Economic history and development economics are the main fields from which Vermeulen (2018) derives the requirements for both strong political and economic institutions, leading to prosperity. These are an open political system, fair taxation, distributional systems, and rules for free association for the political institutions and property rights, land and resources ownership, price formation and open markets and rights of workers and consumers for economic institutions (ibid.). To translate these requirements into useful metrics for the private sector, the focus ought to be less on the costs a product causes, but rather what kind of activities private actors undertake to improve or adhere to political and economic institutions.

3.3 Definition of measurement assessment terminology

The terminology used to describe the differing measurement approaches in terms of their hierarchical relationship is adopted from Sala et al. (2013, p. 1662) and presented in Figure 2. Given most of the measurement approaches are expected to be LCT based and Moraga et al. (2019) followed the same approach in their review of circularity indicators, the terminology Sala et al. (2013) propose is deemed appropriate for this review. The clarification of relations between the different concepts is central, because scholars often use them in differing ways (Moraga et al., 2019).

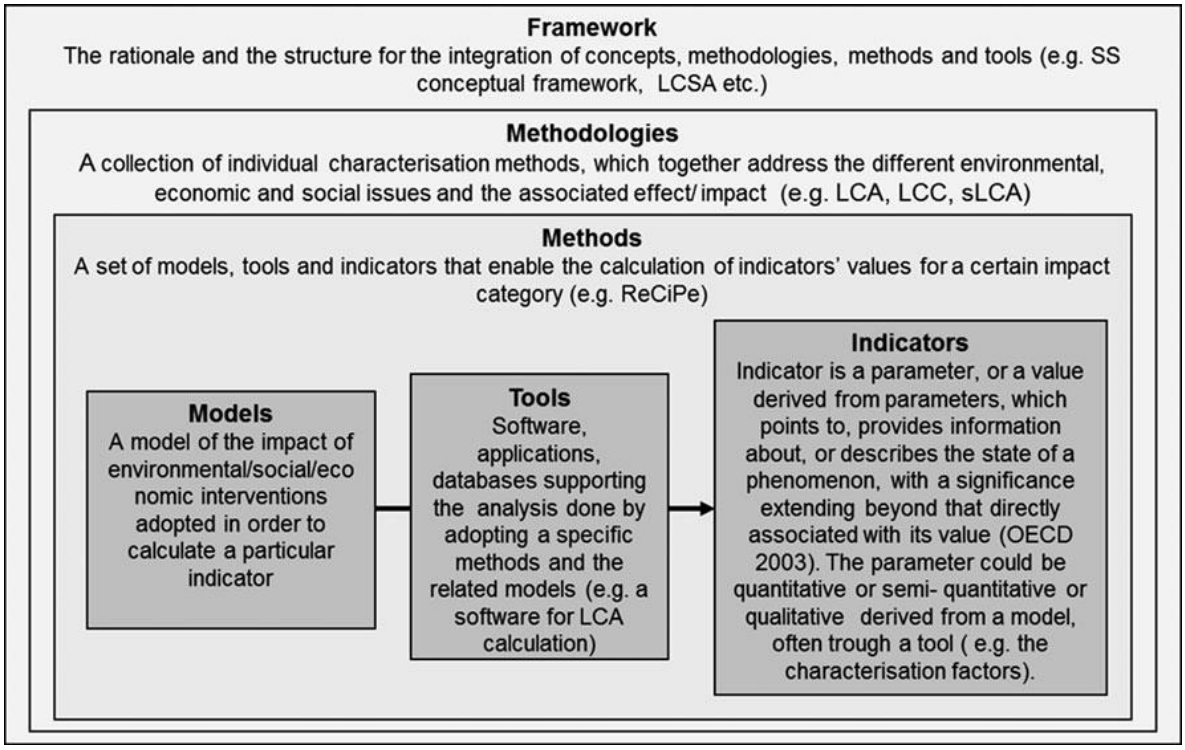

Figure 2*. Terminology of performance measurement approaches (from Sala et al., 2013, p. 1662).*

The overarching approach is a measurement *framework*, integrating rationale and structure of methodologies, methods and tools. One example would be the LCSA. A hierarchical level lower are the *methodologies*, which integrate different characterisation methods individually, assessing for example the three sustainability pillars. *Methods*, in turn, are defined as a collection of models, tools and indicators which allow the quantification or description of a given impact category, such as the ReCiPe. Finally, models, tools and indicators are all on the same hierarchical level. A *model* helps to visualise the impact of an intervention to establish the value of an indicator. Usually, the model is applied using a software, application or database, the *tool*, combining relevant methods. In the case of the LCA, GaBi or SimaPro are common tools. The parameter which gives information about the current state of a characteristic is an *indicator*. It can be quantitative, qualitative or both and is derived from a model, mostly involving the use of a tool (Sala et al., 2013).

3.4 Definition of system levels of application

To provide structure to the analysis, the measurement approaches are to be sorted according to the different system levels of application. The terms micro, meso and macro level have been used inconsistently by scholars both within and across different research fields, which is why a clarification is required (Moraga et al., 2019). For this paper, SA approaches for CE practices applied on a national, regional, provincial or city level are on the macro level (Reike et al., 2018). The meso-level in this research is based on IE understanding, as IE is one of the main theoretical concepts underlying the CE (Bruel et al., 2019; Ghisellini et al., 2016). This level includes the inter-firm connections of companies, which can either be geographically concentrated in EIPs or based on the life-cycle of a product along its supply chain (Korhonen, 2002). Therefore, the CE definition in the introduction needs to be adapted slightly so the meso level does not only consist of EIPs but of inter-firm relations more broadly. In addition to the micro level assigned to single firms, more and more researchers have also advocated for the introduction of a nano level, used for products (Saidani et al., 2017). To ensure consistency, the authors have to reclassify some of the measurement approaches, e.g. from a micro to nano level, where the original source did not use the latter category.

3.5 Adapting the research protocol

Given the conceptual considerations above, the literature review protocol from section 2 needs to be populated. In Table 1 a first attempt is made. The review question is developed against the background of CE as a tool to achieve SD, which means that approaches from IE and CLSCM/RL must also be considered. This is operationalised in the selection criteria which ensure the paper has to do with either measurement of sustainability aspects of CE practices or of IE, IS, CLSCM and RL. While for explicit CE measurement approaches the number of sustainability dimensions addressed is not a limiting factor, the authors propose to include publications on IE, IS, CLSCM and RL only if they measure at least two sustainability dimensions to limit the amount of results. Also, methodologies related to energy and emergy approaches are not included due to the indirect nature of the impact of energy use on product life cycles (Valenzuela-Venegas et al., 2016).

Table 1. *Proposed review protocol (adapted from Tarne et al., 2017, p. 3).*

Review question	• Which measurement approaches have been proposed to assess the sustainability impact of CE practices? • How is the impact on sustainability related to circularity measures?
Selection criteria	Inclusion criteria for publications: • topical on sustainability or CE impact measurement • applicable for at least one industry sector, not just specific product • term sustainability used in the context of three pillars • must adhere to either of the conditions: o must mention circularity or circular economy OR o must include at least two sustainability dimensions (in case it focuses on IE, IS or CLSCM/RL) Exclusion criteria • not in English • book review or duplicate • focused on a specific product or material • mainly addressing energy-related assessment methods such as emergy and exergy approaches
Literature search	*Sources*: academic literature (Scopus, EBSCOHost Discovery), citations in identified literature
	Search phrase: “Circular”, “industrial ecology”, “industrial symbiosis”,

	"eco-industrial park", "closed-loop supply chain", "reverse logistics" or "reverse supply chain" in title and a combination of "sustainability", "performance" and "measurement" in the abstract/keywords; there was no limitation of publication year.
Evaluation	Analysis of assessment type, its link to LCT, the sustainability and circularity dimensions addressed, the way in which the social dimension is integrated into assessments, the way the economic dimension is operationalised and the system level of application

Scopus and EBSCOHost databases are to be searched in parallel with the search phrases in Table 1 to ensure coverage of relevant academic publications.

In the evaluation of the literature review the measurement approach has been analysed in line with the terminological hierarchy of assessment types defined before. Besides elaborating on the sustainability dimensions and circularity addressed, another focus lies on how the social dimension (if present) is integrated within the SA and how the economic dimension is operationalised on the different system levels. It is expected that the latter dimension is mainly represented in terms of direct costs (Vermeulen, 2018).

3.6 Adapting the qualitative survey

3.6.1 Linking CE understanding to circularity and sustainability measurement in practice

The survey presented in the methods section aims to understand current practice of companies as well as the context they are embedded in. CE means different things for different private actors, who then in turn base their circularity and sustainability monitoring systems on the firm or network specific interpretation of the concept. Company size, sector, location and the company's position in the value chain might have considerable influence on the SA approach chosen. Though there has been some initial research on this topic (Cristoni and Tonelli, 2018; Kalmykova et al., 2018; Suárez-Eiroa et al., 2018), practical examples of applied CE measurement are still limited in academic literature. Therefore, the first step is to ask what kind of CE practices the company has implemented or planned. The operationalisation is mainly taken from Kalmykova et al. (2018) who identified 45 CE strategies, which were aggregated for this survey to 13. A clearer grasp on the actual goal of implementing CE practices also helps to find out what aspects matter to the company and where they are most likely to monitor results. Before suitable SA approaches for CE practices can be proposed, it needs to be understood what companies view as CE practices. For this, several conceptual papers on CE were analysed and the main characteristics extracted (Geisendorf and Pietrulla, 2018; Geissdoerfer et al., 2017; Ghisellini et al., 2016; Kirchherr et al., 2017; Korhonen, 2018; Prieto-Sandoval et al., 2018; Reike et al., 2018; Suárez-Eiroa et al., 2019; Urbinati et al., 2017). The characteristics are the R-frameworks, e.g. 3Rs or 4Rs, general maintaining of material value, product durability, designing out waste or closed-loop design with zero waste, product service system (PSS) business models, eco-efficiency and resource efficiency. After asking respondents on the importance of these characteristics for their company's understanding of CE, the link of CE and sustainability is assessed by posing the question on how CE relates to each of the sustainability pillars. Then, the most prevalent ways of measuring both CE and sustainability in a company are listed in the survey and companies are asked whether they use them to assess the corporate sustainability impact. This list is taken from the results of the literature review and inputs from private partners of the research project which are specialised in sustainability and life cycle-based assessments. Finally, the context of the company is established through asking questions on how companies view the importance of drivers and barriers to pursue CE practices for themselves and for other companies. Tura et al. (2019), de Jesus and Mendonça (2018), Ranta et al. (2018) offered the main sources of institutional, economic as well as societal drivers and barriers for the advancement of CE in this survey.

3.6.2 Addressing potential survey errors

Given the sampling is a purposive sampling (Hibberts et al., 2012) there is a higher possibility of sampling bias, meaning that the probability of some respondents to be chosen is smaller than it should be to be representative (Bautista, 2012). This would

mean that some of the CE networks relevant to this research were not be included. It is therefore vital to consult with CE experts in the respective countries after an initial desk research to ensure the important national networks are covered. Further, the coverage error, occurring if respondents within the predefined sampling frame are missing (ibid.), could also decrease the accuracy of the results. Updated member lists as well as contact data can limit the coverage error.

Another pertinent source of result distortion is the non-response error, occurring if sampled populations do not answer the survey (Bautista, 2012). Web-based surveys distributed via pre-defined lists have shown to have the highest respondent rates, as following up with reminders is facilitated and invitations can be personalised (Lozar Manfreda and Vehovar, 2009). Therefore, contact was established with the coordinators of the CE networks to help with the distribution of the questionnaire. As the coordinators are not be able to hand out company data due to privacy reasons, they offered to send prenotification to their members, thus potentially reducing the unit non-response (Manzo and Burke, 2012). While unit non-response means a respondent does not answer the whole survey, item non-response means that some parts of the survey are left out (Andrews, 2003). While this does still generate data, there is the potential of a measurement error. This is the case, if e.g. companies of a certain size or sector chose not to answer a certain survey section leading to skewed results. Respondents can be forced to give answers, but if they are required to fill all answers, there is a higher likelihood to abandon the survey pre-emptively (ibid.). Therefore, just the descriptive company data essential for the analysis is requested in the beginning of the survey. Both item and unit non-response is also assumed to be lowered because the topic of the survey is relevant to the target group and additional learning on the topic is enabled (Albaum and Smith, 2012). Offering companies to be updated on the research results and getting market insights from their business peers is another incentive for participation (Andrews, 2003).

4. Conclusions

This paper has set the foundation for establishing how to measure the effect of CE practices on sustainability aspects. Indeed, to ensure CE does not only increase the economic performance of companies, but also delivers on its promises regarding the social and environmental dimensions of sustainability, it is vital to measure the impact of CE practices. A mixed methods approach is proposed, including a literature review to determine the academic perspective and a qualitative survey, showcasing how CE and sustainability measurement are connected in practice. As the CE is a fuzzy concept, the authors seek for measurement approaches already practiced in IE and IS for geographically demarcated CE practices and in CLSCM/RL for product cycle-based CE practices. Both these operationalisations of CE have a reputation of marginalising the social sustainability dimension, which must be addressed when developing measurement approaches. At the same time, current measurement approaches mostly focus on profit and feasibility-based indicators which do not correspond to the economic sustainability dimension defined here. Therefore, new economic indicators related to political and economic institutions that facilitate prosperity are needed. In the absence of these considerations, CE would risk becoming a purely profit-driven endeavour, potentially having adverse effects on sustainability aspects. Finally, it is important to follow a clear terminology when addressing the different hierarchical levels of measurement approaches and system levels where these approaches are applied.

It is acknowledged that this paper focuses mainly on measurement approaches associated with IE and CLSCM/RL as they were found to be the most prevalent in academic literature. However, other fields such as eco-design, performance economy, biomimicry and waste management could evidently offer additional measurement. Since these fields also work with LCT based measurement approaches, the two chosen fields seem justified nevertheless. Another limitation concerns the two countries chosen for distributing the qualitative survey. The sample is not aiming to be representative for all CE companies but is mostly focusing on representing the corporate landscape spearheading CE in Europe. Those two countries being among the leaders in implementing and measuring the impacts of CE practices was another reason for their choice.

Based on the findings and considering the limitations above, a preliminary research protocol is presented, and the structure of the survey outlined to meaningfully address the research question. A discussion on potential survey errors presents practical

input on the sampling, outreach as well as incentives to participate. Based on this framework, future work is aimed at both conducting a systematic literature review and juxtaposing the results to the practitioner perspective. Identified gaps and overlaps will provide input for improving existing measurement approaches from a pragmatic point of view.

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